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TIKAL TIMBERS AND TEMPLES: ANCIENT MAYA AGROFORESTRY AND THE END OF TIME

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Tikal, a major lowland Maya civic-ceremonial center in the heart of the Petén region of Central America, relied heavily on the adjacent lowland rainforest as a resource base for fuel and construction materials. In this study, we analyzed 135 wood samples from timbers used in the construction of all six of the city's major temples as well as two major palaces to determine which tree species were being exploited and to better understand ancient Maya agroforestry practices during the Late Classic period. We found evidence for a change in preference from the large-growing, upland forest species, Manilkara zapota*, to a seasonal wetland species* Haematoxylon campechianum *in A.D. 741 as well as a decrease in lintel beam widths over time. Though* M. zapota *later returned as the wood species of choice in A.D. 810, beam widths were found to be significantly smaller. These findings concur with models that hypothesize widespread deforestation during the Late Classic period and indicate a declining forest resource base by the 9th century A.D. Also, because of the many large timbers used in temple construction, some system of forest conservation is suggested for the ancient Maya prior to the Late Classic period.*

1. Introduction

Tikal, one of the foremost polities of the ancient Maya realm, (Fig. 1), has fascinated archaeologists for more than a century, not only because of its stunning architecture and rich iconographic heritage, but also because of the inhabitants' ability to sustain large populations in the midst of a tropical rainforest environment. A lingering mystery of the ancient Maya world has been the sudden abandonment of Tikal and other major polities during the ninth century A.D., after which time little epigraphic documentation remains. Theories surrounding the Maya collapse range from overpopulation, class conflict, warfare, and disease, to climate change, deforestation, soil erosion, and agricultural shortfalls. Among these theories, it has been suggested that conditions caused by rapid population growth along with the taxing effects of clear

cutting and extensive and exhaustive agriculture may have put undue strain on the environmental sustainability of the region (Haviland, 1970; Lentz, 1991; Montgomery, 2001).

Paleoenvironmental data from lakes and reservoirs in the Petén region show evidence of increased erosion, nutrient loading, varying degrees of drought and a shift from high forest to disturbance pollen assemblages (Anselmetti et al., 2007; Binford et al., 1987; Curtis et al., 1998; Dunning et al., 1998; Dunning and Beach, 2000; Hodell et al., 2000; Brenner et al., 2002; Rice, 1996; Wahl et al., 2006 and 2007; Deevey et al., 1979; Islebe et al., 1996; Leyden, 1987; Rosenmeier et al., 2002; Rosenmeier et al., 2008; Tsukata and Deevey, 1967; Vaughn et al., 1985; Wiseman, 1978). Pollen profiles derived from these studies provide an indication that there was a reduction in forest cover throughout the Classic period coupled with an increase in land converted to agricultural production. The arboreal (tree) pollen signature, although greatly reduced during the Late Classic period, continues to be measurable, indicating that forested areas were still in evidence in the region even into the Terminal Classic period. Within the Petén, there was also considerable variation between individual watersheds in the chronology and severity of deforestation and soil loss (Anselmetti et al., 2007; Beach et al., 2006; Dunning et al., 2006).

At its zenith in the eighth century A.D., Tikal covered a minimum area of 123 km^2 which supported a population estimated at 45,000 (Haviland, 1970), 60,000 (Culbert et al., 1990), 80,000 (Dickson, 1980), and even as high as 284,857 people in the civic ceremonial center (Turner, 1990). Tikal's population is thought to have peaked in the Late Classic period during Imix times (A.D. 700-830) (Culbert et al., 1990), sometime

after the era of extended warfare known as the Hiatus (A.D. 592-692) in which Tikal suffered heavy military losses (Harrison, 1999; Martin and Grube, 2008). It likely wasn't until the more prosperous Imix times that the city needed to support its peak population in full, a time that also boasted the greatest number of construction projects in the polity's history. This period of prehistory, with its burgeoning population and ambitious building schedule, undoubtedly witnessed a heavy demand on the resources of the surrounding forest.

In this study, we examine the essential wood components of the most prominent of the Late Classic period construction projects at Tikal: the temples and palaces of the city's central district (Fig. 2). Our working hypothesis is that the agroforestry practices of the ancient Maya at Tikal would have changed through time as wood resources became scarce and changes in the wood supply would be reflected in the selection and quality of timbers incorporated into the polity's major structures throughout the Late Classic period. The chronological assessments of structures follow glyph translations and Gregorian date conversions (Harrison, 1999; Martin and Grube, 2008) coupled with radiocarbon dates taken from the lintels and beams themselves (e.g.,Satterthwaithe and Ralph, 1960; Ralph, 1965; Stuckenrath et al., 1966). Because dates inscribed onto lintels are often commemorative and somewhat variable (Coe et al., 1986), dedicatory dates are taken as the latest date inscribed on the structure or its accompanying stela. Where dedicatory inscriptions or radiocarbon dates are unavailable, generally accepted style ranges, referencing inscriptions from other locations, and stratigraphic or geometric relationships to other structures are used to determine the structure's relative chronology (Table 1). A

brief description of each of the structures investigated in this study is presented below in the order in which they were constructed.

1.1 Temple II

Located at the epicenter of Tikal on the west side of the Great Plaza, Temple II is one of the icons of ancient Maya civilization. The building embodies many of the characteristics of Classic Maya temple architecture: it is a tall, multi-terraced pyramid spanned by a single exterior stairway, supporting a small rectangular building, which is topped by an elaborately carved stone roof comb. The three-terraced temple now stands about 38 m high and contains three rooms. The building consists of two main parts as viewed from the exterior and houses a series of slender rooms, each behind and a few steps higher than the former, separated by thick doorways spanned by wooden lintels. Its outermost lintel (Lintel 1) is uncarved, as is the norm at Tikal, however, the innermost lintel (Lintel 2) portrays a young woman thought to be the wife of Jasaw Chan K'awiil I, Lady Lachan Unen Mo' (Sharer and Traxler, 2006). She also may be the personage portrayed with elaborate earplugs and ornamentation on the temple's roof comb. Also known as the 'Temple of the Masks,' Temple II is thought to have been constructed at the end of the seventh century (Coe et al., 1986). The construction of Temple II marks the ascendancy of Lord Jasaw and, along with Temple I, was the crowning architectural achievement of an era of rejuvenation at Tikal brought about by this great lord.

1.2 Temple I

Temple I, also known as the Temple of the Giant Jaguar, covers the tomb of Jasaw Chan K'awiil I. The building stands about 47m tall and consists of nine terraced

sections supporting a three-roomed temple building. Jasaw is depicted on Lintel 3, seated atop a throne and guarded by a giant jaguar in celebration of his defeat of rival political power Calakmul in A.D. 695. Jasaw's likeness appears on the temple's roof comb, as well. While Jasaw probably played a large part in the design and construction, the temple most likely was completed after his death in A.D. 734 by his son and successor, Yik'in Chan K'awiil. The most recent associated date is from corresponding texts on Stela 25 from the year A.D. 711 (Coe et al., 1986).

1.3 Temple IV

At 70 m to the top of its comb, Tikal's Temple IV is the tallest standing New World Precolumbian structure (Coe, 1967). Located at the far west end of the city center, Temple IV faces Temple I and with it, the rising sun. The structure was built under the reign of Yik'in Chan Ka'wiil (Coe et al., 1986; Ralph, 1965) during an era of unprecedented building, presumably funded by Yik'in's victories over the kingdoms of Kan (A.D. 736), Waka (El Perú) (A.D. 743), and Naranjo (A.D. 744) of the Calakmul alliance (Harrison, 1999). Lintels 2 and 3 depict Yik'in enthroned atop giant palanquins surrounded by various celestial symbols and emblems of the conquered cities. It has been suggested that Yik'in's tomb may lie beneath the temple, although burial 196 at pyramid 5D-73, which bears several similarities to that of Jasaw's grave, has also been proposed as his final resting place.

1.4 Palace of 5 Stories (5D-52)

At the heart of the Central Acropolis is an extraordinary structure now known as the Palace of Five Stories. Each floor consists of two galleries, one in front of the other, with the fore gallery of each floor set over the rear gallery of the floor beneath, imparting a stepped appearance. The palace consists of two separate construction projects: the lower two floors (5D-50) originating from the Early Classic period (Harrison, 2001), and the upper three (5D-52) (Coe et al., 1986) of Late Classic construction from which all samples studied originate. The central interior doorway of the first floor of 5D-52 (the third floor of the structure as a whole) is carved with what Coe and others refer to as "domestic quality" iconography (1986), which nonetheless represents a rare example of non-temple lintel elaboration. The lintel bears the dedicatory date of A.D. 741, however it is thought that a large part of the construction effort continued after this date (Coe et al., 1986). The structure is not considered to have served as a permanent residence, but rather a building of officious or ceremonial retreat, possibly a men's retreat house (Harrison, 1970).

1.5 Temple VI

Far to the southeast, at the end of the Mendez Causeway lays Temple VI, also known as the Temple of the Inscriptions, the most recently discovered and unusual temple at Tikal. Temple VI represents a sharp stylistic break from previous Late Classic temples, exhibiting a squat, wide style, with three frontal doorways more characteristic of Preclassic design (Harrison, 1999). The building's enormous roof comb supports an elaborate text detailing the history of Tikal, from its prehistoric settlement to a final inscribed date of A.D. 766, taken as the date of construction (Coe, 1967). Stela 21, in

front of the temple commemorates the inauguration of Yik'in Chan Ka'wiil in A.D. 736, who is thought to have orchestrated the temple's construction, though completion may have been overseen by Yik'in's son, intermediary Ruler 28, before he ceded power to Yax Nuun Ahiin II (Martin, 2003).

1.6 Maler's Palace (5D-65)

Directly to the east of the Palace of Five Stories in the Central Acropolis is the structure known as Maler's Palace, named for its Austrian discoverer, Teobert Maler, who took residence in it during his explorations in 1895 and 1904 (Coe, 1967). The structure consists of two rows of adjacent rooms, with terminal chambers set at right angles, giving an aerial appearance of a capital "I." An enormous undertaking, likely requiring a labor input comparable to construction of Temple VI (Harrison, 2003), the ground level of Courtyard 2 had to be raised by a full five meters of solid fill to support the building (Coe, 1967). The only asymmetrical room in the palace is such that it provides a direct line of sight from Temple I to Temple V, suggesting contemporaneous construction with the latter (Harrison, 2003). The palace likely served as a seat of civic and religious ceremony.

1.7 Temple V

Just south of the city center, staring past the Central Acropolis toward Temple I is Temple V – at 57m high, the second tallest temple at Tikal. Temple V temple has rounded corners and raised moldings along the stairway that leads to only a single tiny room (Coe, 1967). Although one study, based on ceramic correlations, assigns the time of

construction of the temple to the mid-7th century (Gómez, 1999), most scholars attribute the temple to the reign of Yax Nuun Ahiin II in the 8th century based on radiocarbon dates (Coe, 1967) and structural affilations and alignment with Maler's Palace (Harrison, 2003; Sharer and Traxler, 2006).

1.8 Temple III

The final temple at Tikal is perhaps its most mysterious, leaving behind little evidence as to the city's downfall. Temple III, known as the Palace of the Jaguar Priest, measures 55 m in height and aligns with not another temple, but with the Central Acropolis and Structure 5E-38. Stylistically, it bears many resemblances to the earlier temples of Jasaw's reign, yet houses only two rooms at its peak and retains the raised stairway moldings of Temple V (Coe, 1967). Lintel 2 within portrays a corpulent official (Fig. 3) cloaked in a jaguar skin and flanked by attendants. The figure is assumed to be the ruler Dark Sun named on Stela 24 at its base (Martin, 2003; Montgomery, 2001), but this translation is not certain. Stela 24 is clearly dated A.D. 810 (Coe, 1967) although temple construction may have continued until as late as A.D. 830 (Montgomery, 2001). After this point there remain few inscriptions or monuments at Tikal. Only a single later date is recorded at the polity, inscribed upon Stela 11 in the Great Plaza at A.D. 869, associated with another ruler Jasaw Chan Ka'wiil II (Sharer and Traxler, 2006). Most of the rural areas surrounding Tikal appear to have been deserted from 830-950, while lesser outlying sites begin to exhibit signs of autonomy (Martin and Grube, 2008; Webster, 2002). By A.D. 950, Tikal appears to have been completely abandoned.

2. Methods

To learn what woods were used in temple and palace construction and to better understand the Late Classic Maya interaction with the forest environment, we conducted morphological analysis of 135 samples (Table 2) taken from remains of structural woods at all six of the polity's major temples as well as two palaces from the Central Acropolis to determine what species were being exploited. Nearly all of the samples were in-situ at the time of collection and the dates of building construction were either recorded on dedicatory stela or interpretable from archeological evidence, giving us an accurate picture of chronology.

All samples were collected during excavations led by the University of Pennsylvania between 1956-1970 and are either from tie-beams, which support a structure's ceiling, or lintels, a series of beams that span and support doorways (Fig. 4) and often depict elaborately carved scenes. Measurements taken from surviving lintel beams or their remaining imprints (Coe et al., 1986) were analyzed to gauge the size of trees available for construction at the time. Many of the wooden beams used in temple construction were from trees large enough to be representative of old-growth forests. The wood samples examined in this study, initially collected for radiocarbon dating purposes, were obtained as a loan from the University of Pennsylvania Museum of Archaeology and Anthropology where they were stored pending final analysis.

Small sub-samples (1 cm^2) of each wood specimen were sawed, smoothed with a razor blade, and preliminarily analyzed using a Leica S6D stereomicroscope at low magnification (35X). They were then sorted into wood types based on specific morphological characteristics, viz., arrangement of vessels, rays and parenchyma cells.

Representative samples of each wood type were sealed in aluminum foil, buried in a sand medium and heated in a covered metal container over a propane stove for 3 ½ hours to carbonize them. Carbonized samples were then fractured, mounted with colloidal graphite, and scanned in an Amray 1810 scanning electron microscope at the Field Museum of Chicago. Micrographs were taken at 50x and 100x magnification, and wood types were identified through comparison with vouchered wood collections and text references.

3. Results

From our analysis, we learned that only two tree species were utilized as beams and lintels in the construction of the two palaces and six major temples of Late Classic Tikal. The most commonly used tree species, *Manilkara zapota* (L.) P. Royen (Fig. 5), is locally known as sapodilla, mamee apple, chicozapote or ya. It is a native tree of moist, mixed forest of slow-to-moderate growth that can reach heights of 30-40 m with a trunk diameter of 1.5 m (Standley and Williams, 1967). Today, this tree is common in the adjacent forests to the west and south of Tikal and there is every indication that the tree would have found suitable habitat there in ancient times, as well. The edible fruits of sapodilla are relished by modern Maya, who use its seeds and bark as a medicinal paste or tea (Balick, 2000; Morton, 1987; Rocas, 2003). Sapodilla is often cultivated by the Huastec Maya (Alcorn, 1984) and ladinos in the region (Breedlove and Laughlin, 2000), mostly for its fruits. The tree's milky latex, *chicle,* is the principal component of natural chewing gum and continues to be among the local nontimber forest products (Mickelbart, 1996; Standley and Williams, 1967). Although it is difficult to cut, the wood is hard, durable and highly wear resistant (Aguirre de Rojas and de Poll, 2007). The timber is

traditionally worked or carved while it is still green, when it is more workable, then allowed to dry to iron-like hardness. Because of these qualities, it is believed that the lintels of Tikal were carved from fresh timbers and not of recycled wood (Coe et al., 1986).

The second tree used in temple or palace construction, *Haematoxylum campechianum* L. (Fig. 6), is a shorter, slow-growing tree that is locally referred to as logwood, inkwood, tinta or ek. Modern Maya use it as a source of dye, which is extracted through the boiling of its wood or bark, and also as a source of medicinal tea (Balik, 2000; Rocas, 2003). Reaching a maximum height of 8 m, its often-crooked trunk becomes fluted and gnarled with age (Standley and Williams, 1967). The spine-covered tree requires clayey soil and is tolerant of standing water (Rocas, 2003). It likely would have grown successfully in the seasonal wetlands flanking the city, most notably the sprawling Bajo Santa Fe on the east side of the site core. The heartwood is dense, hard to cut, resistant to insect depredations and highly durable with a fine, but irregular, grain that finishes smoothly (Aguirre de Rojas and de Poll, 2007). Like sapodilla, logwood has the ability to withstand tremendous strain and because of its favorable physical properties it is one of the few timbers of the region that could bear the enormous weight demands typical of temple and palace construction. The ancient Maya builders of Tikal obviously knew this.

Measurements of beam widths for the carved lintels of Temples I-IV and Str. 5D-52 contained in the original Tikal Report No.6 (Coe et al., 1986) were analyzed using a standard analysis of variance test (ANOVA). Differences in beam widths between structures were found to be significant ($F = 11.0$, $p < 0.01$) with widths peaking during the

construction of Temple IV and dropping to the smallest diameter by Temple III. Mean beam widths are shown in Fig. 7. A Student's t-test also was applied between beam widths of Temple III and those of all other structures for which information was available (i.e., excluding Temples V or VI) and differences were found to be significant ($t = 5.83$, $p < 0.01$).

Our results show that lintel beam diameters reached their maximum dimension in A.D. 741 and sapodilla was the only tree species used for temple construction at Tikal for the first three major temples (Temples II, I and IV). During the next approximately four decades, a change in preference from sapodilla to logwood for the construction of Temples V and VI could be observed. A mixture of the two tree species were found in both palaces studied, with the earlier Palace of Five Stories composed primarily of sapodilla with some logwood, while the latter, Maler's Palace, was constructed mostly of logwood with some sapodilla (Fig. 8). In construction of the city's final temple, Temple III, the designers returned to the use of sapodilla wood, though lintel beam diameters were significantly smaller than in previous temples utilizing sapodilla.

4. Discussion

Jasaw's reign and most of Yik'in's was a time of prosperity at Tikal (A.D. 682-751) marked by victories against its regional rival, Calakmul, and the initiation of the largest number of construction projects in the city's history (Harrison, 1999), which indicate a high level of social activity and an intense demand on the surrounding forest. Four aspects of ancient Maya agroforestry and land use practices are suggested in the pattern of wood employed in palace and temple construction.

The first aspect of interest seen in the results of our analysis is that temple construction was carefully planned; the Tikal Maya did not simply begin construction then fulfill their building material needs with whatever wood was available. More likely, construction timbers were selected in advance and an adequate source of large beams was identified during the planning phase of construction. It was no accident that all temple beams were of a more or less uniform dimension and from the same tree species with wood of a quality that could withstand the pressure of a heavy roof-comb. The uniformity of dimension also suggests that the wooden beams were cut especially for a specific temple construction project and not scavenged from an assortment of older buildings. Fresh sapodilla beams were cut, shaped and arranged for carving, probably before their insertion into position as lintels (Coe et al., 1986). The images and texts on the sculpted lintels likely were planned in conjunction with other iconographic elements such as the elaborate stucco facades atop the temples. In contrast, the Late Classic Maya seem to have been less particular about the wood used in palace construction and the data from these structures reflect a greater willingness to use a combination of sapodilla and logwood of varying dimension. Clearly, the choice timbers were reserved for temple construction.

The second intriguing aspect of the wood data from the Tikal temples is the large dimension of the beams themselves. These were timbers of enormous size. According to Dr. Shook's notes, some of the beams had over 40 annual rings even with the outer rings removed during the squaring of the logs prior to insertion in the lintels (Fig. 9). Because the Petén rainforest has more or less distinct wet and dry seasons, the vascular tissue tends to have observable areas of rapid and slow growth, i.e., annual rings. Although the

annual rings in a sapodilla are not as uniform and regular as some trees in regions with a more pronounced seasonality, they do provide an indication of a tree's age if all rings can be counted. The Tikal beams observed by Shook were of considerable age. Ralph (1965) calculated, using radiocarbon dates obtained from different parts of a sapodilla lintel, that the tree would take 10.4 years to increase its radius 1 cm. Ralph's calculations, if correct, indicate that a lintel beam from Temple IV with a radius of 27 cm came from a tree that was over 280 years old. If the sapodilla beams used in temple construction were not from virgin forest, they were certainly from old growth forest. This raises the question about where these large timbers originated. The Tikal area had been occupied for at least 1500 years prior to the construction of the first major Late Classic temple (Harrison, 1999) and the population boom at Tikal began around A.D. 550 (Haviland, 1970), two centuries prior to major temple construction. Presumably there was great need for agricultural land during the Late Classic period and the upland forests, where sapodilla trees would have grown, occupied areas best suited for agriculture. The fact that such large trees were available when population pressures and need for agricultural land must have been acute provide a strong indication that the Tikal Maya were practicing some kind of conservation measures in their approach to forest management.

High forest degradation prior to the Late Classic has been indicated by pollen studies, but even in the height of forest clearance in the Late Classic, some high forest pollen signature remains. How this conservative approach to agroforestry was actually manifested is difficult to ascertain, but the ethnographic literature provides some insight. One possible explanation for the high forest timbers at Tikal is that they may have come from "ancestor estates" or "inherited forests" as part of a fixed land tenure system

controlled by kinship as seen among the Mam (McAnany, 1998). Ostensibly, the rulers of Tikal had clearly defined kinship ties of long standing and deep diachronic connections that may have given them control of or access to inherited forests (McAnany, 1995). The Itza maintain tended stands of forests called "päk'-al" where sapodilla trees are protected and sometimes planted (Atran, 1993). Some authors (Burman, 1992; Gómez Pompa et al., 1990) describe the phenomenon of "sacred groves" which are patches of vegetation of special species that may be associated with a deity or, for various reasons, exist on sacred ground. Whatever the mechanism, somehow the forests that produced the early temple lintels were from lands being conserved in the face of extreme demographic pressure.

The third intriguing aspect of the temple woods is the change from sapodilla to the logwood of the bajos around A.D. 766 in the construction of Temple VI. This change in construction material preference represents a major shift in resource extraction strategy. It was a move away from the upland forests into the seasonal wetlands where the many difficulties involved in locating, extracting and processing heavy, thorned, and gnarled logwood of sufficient size likely made it a less preferable, but perhaps necessary alternative. Perhaps the best explanation for this shift away from sapodilla to the extraction of logwood is that the Tikal Maya had exhausted the supply of large sapodilla trees and turned to a forested area that had not yet been heavily exploited, namely, the bajos.

The fourth intriguing aspect of temple wood use at Tikal is the return of the use of sapodilla after a four-decade hiatus. Assuming the construction of a temple would have had highest priority for timber extraction in the region, the availability of sapodilla of even 15 cm radius was evidently scarce by the early 9th century as indicated by the much

smaller lintel beams seen in Temple III. At this stage in Tikal history, it appears the builders resorted to the use of trees harvested from less mature second growth forest.

It may be significant that political and social control began a slow decline at Tikal about the time that Temple VI was built. Return to the use of sapodilla, as seen in Temple III, could be interpreted as another stylistic change, as a supply issue where the re-growth of previously cleared upland forest once again made large sapodilla timbers available for construction or perhaps even as an attempt to appease the gods by returning to temple construction methods of the more auspicious Jasaw Chan K'awiil I era. The observed return to a previous construction style may suggest an increasing concern for political and economic turmoil by the ruling elite at a time just antecedent to the collapse.

5. Conclusion

It is likely that much of the upland area around Tikal and other major centers had undergone deforestation for agricultural purposes beginning as early as 1000 B.C., though some areas of managed forest seemed to have remained intact into the Late Classic period. Patches of prime timber were likely the property of the ruling elite, but even these were eventually exhausted around Tikal and probably in other areas of the Maya realm, as well. From our study of temple lintels at Tikal, we were able to determine that the time of removal of the last of sapodilla from old growth upland forest in the Tikal area was around A.D. 750. Subsequently, logwood timbers were extracted from bajo areas. Apparently, during periods of increasing need for agricultural land leading up to the Late Classic period, the Maya carefully managed their forests, otherwise there would have been no tracts of intact old growth forest after 17 centuries of forest product

utilization by an expanding human population. Ultimately, however, toward the end of the Classic period, our evidence shows that timber resources were becoming exhausted, at least in terms of those woods required for elite construction projects, and whatever conservation practices had been in effect during the time leading up to the Late Classic period, eventually were abandoned.

Changes in wood use patterns at Tikal likely indicate the dwindling availability of an over-harvested forest timber resource. These data support the paleoenvironmental evidence for human-induced ecological strain in the lowland Maya area in Late Classic times, and suggests that Tikal's inhabitants became trapped in a positive feedback loop wherein increasing demands on a shrinking resource base ultimately exceeded the carrying capacity of their immediate environs. The ecological lessons learned from the Late Classic Maya, with their meteoric population increase accompanied by environmental overstretch, should serve as a distant mirror for our own cultural trajectory.

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